REPORT II

ANNUAL PROGRESS REPORT II FOR 1984-1985 JOINT KENNECOTT UTAH COPPER DIVISION (UCD) MINE HYDROGEOLOGIC STUDY

Reviewed by the Utah Ground-Water Technical
And
Advisory Group Members

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INTRODUCTION

This report is the second of five annual data summary progress reports for the five-year joint ground and surface water investigation for the mine area at Kennecott's Utah Copper Division (UCD), Salt Lake City, Utah (Figure 1). This report summarizes the preliminary findings based on historic (1975-1982) hydrogeologic data and the first two years of comprehensive hydrogeologic data from the five-year study (1983-1985).

The technical work has been conducted by Kennecott, Dames & Moore Consultants, Intera Technologies, and has been overseen by State and Salt Lake City-County technical staff (The Technical Group), with non-technical issues overseen by Kennecott, State and Salt Lake City-County administrative staff, (The Advisory Group). State members are from the Utah State Division of Health, and City-County members are from the Salt Lake City-County Health Department. A list of the Technical and Advisory Group Members is presented in Table 1. The Technical Group also receives informal technical input from several other agencies in order to ensure completion of sound technical work throughout the project. These are also listed in Table 1.

A Kennecott/UCD Mine Hydrogeologic Study Citizen's Advisory Council was established in early 1985. A list of these participants is also included in Table 1. The purpose for this council is to inform the local citizens and interested parties of the progress, critical issues, and results of Kennecott's and the Technical Group's work during the course of the five-year joint UCD mine hydrogeologic study. This council meets on a quarterly basis, or more frequently when necessary.

This report includes: (1) Historic (1975-1984) water quality data, (2) Rounds 1 and 2 field and laboratory hydrogeologic and water quality data from years one and two of this five-year study, (3) Kennecott's work plan, quality assurance document and responses to state, county and federal agencies' technical concerns, (4) Kennecott's 1985 surface water management plan, (5) Preliminary conclusions, and (6) Recommendations on future sampling and new monitor well completions.

This report reflects the work effort of Kennecott and the Technical and Advisory Groups over the first two years of the five-year study. Dames & Moore and Intera Technologies, Kennecott's consultants, have reviewed this report along with the Technical and Advisory Groups.

Geologic data and the water quality data available for this report from the four new monitor wells completed in the winter of 1984 are included in Appendix B. These wells were drilled primarily for water quality purposes, to determine if the historic ground-water quality data at three existing adjacent well sites were representative of aquifer conditions at those sites. The very poor quality water found at existing well site P198 appears to have been impacted from shallow seepage infiltrating down along the casing. This is based on the better quality waters found at new monitor wells P239 and P240A and B, respectively. The very poor quality waters at existing well site P202C, located approximately 1.75 miles southeast of the reservoir, appears to be representative of a deep contaminant zone at around 600 feet. Recent (June, 1985) field water quality from new monitor well P241B verifies this to be the case at this site.

Purpose

The purpose of this report is to summarize the results of the hydrogeologic and hydrologic work conducted since the beginning of the joint UCD hydrogeologic mine study in June of 1983, with major emphasis on the work and new data obtained in 1984-1985 and the Round 2 water quality sampling results. This report is structured nearly identical to the first annual report. Many of the conclusions in the first annual report are supported by the data obtained in Round 2 sampling.

Scope

The entire five-year study is to accomplish and complete the following:

1. Evaluate the natural resources, the socioeconomic conditions, hydrogeology and hydrology in the vicinity of the Bingham Canyon Mining District (partially completed by the EAS (October, 1984)).

2. Assess the historic (background) and existing ground and surface water quality conditions in the vicinity of the Bingham Canyon Mining District, particularly with respect to the impacts from Kennecott's mining operations (to be completed by Intera, 1985-1986, refined as new water quality data are obtained).

3. Obtain the necessary hydrogeologic and geochemical data required to evaluate the lateral and vertical extent of ground-water contamination (Phases I and II drilling, 1985-1986; Phase I drilling will evaluate on-site as well as potential existing off-site releases; Phase II drilling will evaluate on-site contaminant sources).

4. Estimate contaminant movement in the groundwater based on source areas, actual field and laboratory water quality data, water level data, analytical and numerical solutions to ground-water contaminant flow equations (preliminary contaminant flow modeling 1985-1986).

5. List the potential remedial actions, for implementation, to solve the ground-water contaminant problems.

6. Five annual progress reports and a final environmental impact assessment (1989). This report constitutes the second of the five annual progress reports. The data and evaluations included herein were completed as part of the total work effort listed in 1-5 above.

Report 1, (June 1984), summarized published hydrogeologic data pertinent to the study and presented geologic, hydrologic and hydrogeologic data which Kennecott obtained in the mine area. Round 1 water quality results were also included.

Most of the Round 1 (1983-1984) comprehensive laboratory water quality data results from existing Kennecott monitor wells, surface water sites and private wells (excluding several irrigation wells) and 1982 water quality data were evaluated and were included in Report 1. Any additional Round 1 1984 water quality data, historic water quality data from 1975, natural resource data and socioeconomic information were presented in the EAS (October, 1984). This second annual report includes the historic water quality data from 1975 through Round 1 sampling and the water quality data collected in Round 2 that were available at the time of this report preparation.

Definition of existing ground and surface water conditions is still somewhat difficult and must be considered as preliminary, subject to change as the historic water quality data are evaluated in detail as additional comprehensive hydrogeologic data and water quality data are obtained from new strategically located monitor wells.

PRELIMINARY CONCLUSIONS

As stated previously in Report 1, Kennecott (1984) and the EAS (Environmental Assessment Status Report) (1984), historic subsurface geologic and water quality data as well as the recent (1983-1985) data strongly indicate that there are two and possibly three aquifer flow systems in the study region. Based on subsurface data on-site, thick (several hundred feet) zones of low permeable silt and clay, with thin gravel lenses, separate a shallow unconfined aquifer from a deeper confined (principal) aquifer (Appendix B). A confining zone, in the classical sense (e.g., a distinct continuous clay/silt zone of known thickness, 10-50 feet thick) may not be present throughout the study area. Subsurface geologic data obtained from the historical records and limited drilling in 1984 verify that a zone (or zones) of low permeability silt and clay generally separates the shallow permeable beds from the deeper permeable zones.

The upper shallow aquifer near Kennecott's leach dumps, the Bingham reservoirs (the 500 and 20 million gallon), the evaporation ponds and along Bingham Creek has been affected by Kennecott and pre-Kennecott mining operations. The key contaminants are dissolved solids and sulfate, and where low pH (<6) groundwaters are encountered, (primarily around the leach dumps, the reservoirs, and immediately downgradient around the old evaporation ponds), elevated levels of heavy metals are found.

Comparison of Round 1 (1983-1984) and Round 2 (1984-1985) ground and surface water quality data do not indicate significant water quality changes, with the exception of elevated TDS and sulfate levels in private wells W337 and W338 downgradient from the old evaporation ponds (Figures 2 and 3). In fact, the reservoir and quality of the groundwaters directly downgradient from the reservoir have improved slightly, and/or remained fairly stable since last year (i.e. S200, K105, K84, K72, P213B,C).

Water quality data from two sets of wells near Kennecott's facilities which may show some trend increases are wells P202C, P191A, P190A, W167 and W339. Increased TDS, along the Bingham Creek drainage, primarily from increased sulfate concentrations were observed in wells P191A and P190A, whereas the increased TDS in wells W167 and W339 were due to both increased sulfate and increased chloride levels. It is important to note, however, that wells between well W167, and to the west, along the Bingham Creek drainage, closer to Kennecott facilities (i.e. wells W189 and K109) showed improved water quality or stable levels with respect to 1983-1984 Round 1 data. Similarly, although well W339, located near the new evaporation ponds, showed increased TDS, wells W310 and 311, closer to the new evaporation ponds, showed improved water quality or stable levels with respect to 1983-1984 Round 1 data.

As would be expected, water levels in nearly all of the Kennecott monitor wells rose in 1984-1985 as a result of the large amounts of recharge over the past three years. This is especially true of the deeper monitor wells.

The water quality changes in the southwestern part of the study area may reflect the influence of above average recharge and a subsequent "flushing" of the aquifer. Surface sites S22A and S22B along Butterfield Creek and wells P234, P228, W125, W41 and W323 showed increased levels of TDS primarily from increased sulfate levels and to a lesser extent from increased chloride levels. It is of particular interest to note the elevated chloride levels at these sites, as chloride concentrations historically appear to be slightly elevated in this part of the study area.

Historic and current (Rounds 1 and 2) water quality data from existing and new (1984) deep wells that monitor groundwaters in the deeper confined (principal) aquifer generally support the preliminary 1984 results that water quality degradation from mining is principally limited to the upper shallow aquifer. Deep monitor well construction and sampling scheduled for 1985-1986 (Phase I) and 1986-1987 (Phase II) will aid significantly in determining the extent of deep aquifer contamination. The deep (principal) aquifer in the western part of the Jordan Valley, although generally of high yield, has TDS and sulfate levels that commonly exceed federal EPA and Utah drinking water quality standards.

Water quality data from the two private wells W337 and W338 located approximately 1.2 miles east-southeast of Kennecott's old evaporation ponds showed elevated levels of TDS and sulfate in late 1984-early 1985. Excess surface water discharge in 1982-1984 to the old evaporation ponds may have reached these well sites in late 1984. The poor quality waters may also be due to leaching effects of record precipitation through materials discharged in this area over historical time. Both wells were pumped for six days, May 7-12, 1985, to try to determine if the seepage waters might have flowed down along the sides of the wells' casings. No changes in water quality were observed. Both well owners' water systems are now connected to the South Jordan City water line. These wells are being monitored (sampled) on a monthly basis and two Phase I shallow and deep Kennecott monitor wells are scheduled to be installed near these private well sites. If the subsurface geology and water quality data verify deep aquifer contamination from shallow surface seepage along the well casings, these two private wells may need to be abandoned via grouting.

Water quality data from other private wells near the Kennecott mine facilities indicate that other private wells in the area have not been impacted by Kennecott (i.e. Copperton's production wells two miles north of the Bingham reservoirs, Kennecott's production well two miles east of the Bingham reservoirs, Riverton City's production wells seven miles southeast of the Bingham reservoirs and other private wells).

Two of the key questions to be answered and addressed in defining and implementing the work scope of the five-year joint hydrogeologic UCD mine study are: (1.) What are the existing effects of the historic and current mining operations on groundwaters, on and off-site of Kennecott's property and (2.) What are the potential future effects on groundwaters (i.e. contaminant migration rates and pathways). Continued water quality sampling, subsurface geologic data obtained from Phases I and II drilling, establishment of background water quality levels and preliminary ground-water contaminant flow modeling to be completed in 1985 and 1986, will aid in answering these questions.

FIELD AND LABORATORY PROGRAMS

The field program conducted for Report II completion included:

Field Work

1. Round 2 of Kennecott's annual comprehensive water quality sampling was completed. A total of 47 Kennecott wells, 68 private wells and 41 surface water sites were sampled for Round 2 (Appendix E).

2. Field tests consisted of conductivity, temperature, pH, carbonate and bicarbonate tests.

3. Four replacement monitor wells were constructed in 1984. Wells P239, P240A,B, and P241B were constructed next to wells K67R, P198A,B, and P202C, respectively. Due to freezing conditions at the time P241B was completed, this well was not sampled in 1984. However, P241B was surged, pumped and sampled in June, 1985. Laboratory test results are not yet complete, although field test data are available (Appendix E). The other three wells were sampled with the analytical results presented in Appendix C.

Laboratory Work

1. Laboratory analyses were extensive (Tables 2 and 3). Analyses of 32 constituents were conducted at all sample sites and analyses for 36

constituents (which included coliform and radionuclide analysis) were conducted at a few selected sample sites. Total and dissolved metals concentrations were and will continue to be analyzed. Most but not all of Round 2 data were available at the time of this report completion.

2. Kennecott's Utah laboratory conducts and is certified to complete the analysis for all of the parameters, except radionuclides, which were analyzed by CEP laboratory in Santa Fe, New Mexico.

   The field sample filtration and preservation methods were in accordance with EPA procedures as outlined in EPA's "Methods For Chemical Analysis of Water and Wastes" (1983). Laboratory analyses were conducted according to EPA recommended procedures (1983), and as approved by the Utah Department of Health. The results of Round 1 and 2 laboratory analyses and the field water quality sample sheets are included in Appendices C and E, respectively.

   One borehole geophysical log, the geologic logs and monitor well construction data for the four new monitor wells drilled in 1984 and the Utah State University monitor well are included in Appendix B.

   Figures 4 through 15 are geologic and hydrogeologic maps and drawings which were included in Report I, Kennecott (1984), some of which have been updated as additional data have become available. These are included for reference, but must still be considered preliminary, to be refined as more data are obtained.

QUALITY ASSURANCE

At the request of the Utah State Department of Health and City-County Health Department, and as part of "The Agreement," Kennecott prepared a Quality Assurance Project Plan, Ground and Surface Water Sampling and Project "Work Plan" for the Five-Year Joint Hydrologic Study. This "Work Plan" has been reviewed and approved by both the state and county.

A copy of this work plan is included as Appendix F. The project Work Plan and technical basis for the Phase I Drilling Program are included in the "Work Plan."

WATER QUALITY - ROUNDS 1 AND 2 RESULTS

Summary

A summary and listing of the water quality data included in this section are presented by the isoconcentration maps, Figures 16 through 19 and Appendices C, D and E. Figures 2 and 4 show the location of the sample sites.

The isocon maps prepared for this second annual report are more detailed as a result of additional sample points and a better understanding of the hydrogeologic conditions. Figures 16 through 19 illustrate 1983-1984 data, except at points where the analyses and data input into the computer were not completed at the time of report preparation.

The isoconcentration lines for Round 2, 1984-1985 water quality data are nearly identical to Round 1, 1983-1984. This is particularly evident with respect to pH values and the metals copper, iron and manganese. The isoconcentration lines for zinc and lead have been extended slightly to the east near the Lark tailings, due to the addition of more data control points (Kennecott, (June, 1984)) and chloride isoconcentration contours were prepared to demonstrate the wide variation observed in chloride values throughout the study area.

The isoconcentration lines for sulfate and TDS have been modified as a result of more water quality data points and more data. For example, the isoconcentration lines to the north of the reservoir probably do not extend as far north as previously assumed. However, the sulfate and TDS contours have been expanded east near the Lark tailings and along the southeastern dump area. Refinement of these isoconcentration contours will be possible following Phase I drilling and sample analysis.

Sulfate and TDS contours were constructed around the old evaporation ponds and extended to the northeast and southeast as a result of new water quality data from the Utah State University monitor well and private wells W337 and W338. TDS and sulfate contours were refined in the ground-water discharge area near private wells W300 through W306.

Although chloride is not a contaminant from Kennecott's operations, what appear to be naturally occurring elevated chloride levels have been observed in springs and certain wells in the study area. As shown on Figure 17, 250 ppm chloride isoconcentration lines have been drawn in the southwest corner of the study area, around wells near the new evaporation ponds, at well sites to the east and west of the Jordan River, near the discharge zone near the W300 series wells, and in the north central part of the study area.

Chloride concentrations throughout the study area are highly variable. Bingham pit waters (S237) and reservoir waters (S200) measure low chloride levels at around 109 ppm and 172 ppm. The leach waters S317 in the southwestern corner measure chloride levels of 487 ppm, whereas the leach waters near the reservoir, S236, have low chloride levels (206 ppm). Wells in the southwestern corner show elevated chloride levels, as does Barney's Spring (S318) to the northwest, private wells in the north-central area and in numerous deep and shallow wells and surface sample sites along the Jordan River (Salt Lake County Department of Public Works, 1985).

In the discussions which follow, the term "elevated levels" refers to concentration levels in excess of background concentration levels which are preliminary and are based on current limited upgradient surface water and ground-water data. Estimates of background concentration levels will be evaluated by Intera Technologies based on current and historic water quality data.

SURFACE WATER

Springs and Streams

A total of 29 spring and stream samples and 12 samples from Kennecott's surface water facilities were collected for Rounds 1 and 2 surface water quality sampling effort (Figures 2 and 4 and Appendix C). Four creeks and springs (S316, 318, 319 and 324) from sources upgradient of Kennecott's operations, nine sites along the Jordan River (S1, 2, 38, 54, 57, 166, 330, 313, and 314), fourteen samples from creeks and streams downgradient of Kennecott's operations or in old mining areas such as in the Butterfield Creek and Midas drainages (Figures 2 and 4), were sampled and analyzed.

Evaluation of water quality data results from the surface water sample sites indicate the following:

Butterfield Creek Drainage

Waters from the Bingham mine portal (S21A) and U. S. mine portal (S53) are generally high in sulfate, TDS, iron, arsenic, cadmium, chromium, manganese and zinc. Lead levels are low at both sites and pH values are at or above 7. Metal concentrations appear to fluctuate significantly, possibly due to flushing-leaching action as spring flows fluctuate.

Springs along the Butterfield Creek Drainage (S22B and S40) are of fairly good quality. Levels of TDS are around 1000 and 300 ppm and sulfate levels are around 300 and 40 ppm at sites S22B and S40, respectively. Sulfate, TDS and chloride levels were slightly higher in 1984 than in 1983.

Waters from above and below the Bingham mine portal, sites S21 and S21B, reflect waters both unaffected and affected by old mine workings, respectively. The TDS and sulfate levels above the portal are around 700 and 250 ppm and levels below the portal are 1160 and 600 ppm, respectively. Metal levels, such as aluminum, zinc, manganese and iron are elevated in Butterfield Creek below the portal drainage.

Waters from the spring once used by the Town of Lark (S22A) are elevated in sulfate and TDS, at around 850 ppm and 1800 ppm, respectively. Both of these constituent levels rose in 1984.

Springs Upgradient (Unaffected by Kennecott Operations)

Barney's spring (S318) located approximately 1.5 miles northwest of Copperton, has a fairly high TDS level (1450 ppm) probably due to the elevated chloride levels intercepted in this area (Cl = 500 ppm). It is also high in gross alpha levels. Maple Spring and Crystal Spring (S319 and S316) approximately 5 miles northwest of Copperton, do not have elevated chloride and gross alpha levels. Rose Canyon Creek, S324 located approximately 3.5 miles southeast of Copperton, has very good quality water and a low TDS level of 500 ppm. Total dissolved solids at Maple and Crystal Springs are around 500 mg/l and 260 mg/l, respectively. Values of pH were at or slightly above 7 at all four sites.

The water samples taken from Crystal Spring (S316), upgradient from Kennecott's operations and in the Oquirrh Mountains, is of very good quality, with TDS of 264 ppm, sulfate of 14 ppm and chloride levels of 7 ppm. In fact, the water issuing from this spring is of better quality than any other waters in the study area. The fact that the water quality of this spring is so much better than Barney's Spring, which is located closer to the mineralized ore zones, illustrates how the natural geologic conditions may alter the water quality.

Jordan River

The Jordan River samples at 9000 South (S-1), at 9400 South (S-330), 6400 South (S54), 4800 South (S313), 5800 South (S314) and 11500 South (S321) indicate that levels for TDS and sulfate average around 1000 ppm and 300 ppm, respectively. The Jordan River water at the Midas Creek inflow (S321) is of poorest quality with TDS and sulfate levels at around 1900 and 620 ppm, respectively. In general, the water quality along the Jordan River degrades from south to north. TDS and sulfate levels at S2 at 12,300 South are low at around 680 ppm and 150 ppm, respectively.

The water quality in the Jordan River at S38 at 10,600 South and at S57 at 8000 South is fair, at S38, TDS and sulfate levels are around 900 ppm and 200 ppm, and the water quality is considerably poorer at S57, with TDS and sulfate levels at around 1600 ppm and 550 ppm, respectively. TDS and sulfate levels at S166, the southernmost sample site along the Jordan River, is of very good quality, with TDS levels at around 670 ppm and sulfate levels at around 140 ppm.

Miscellaneous Surface Water Sample Sites

Water quality in the Provo Reservoir Canal (S33) at 16150 South 2000 West is very good, with TDS and sulfate levels at around 240 and 250 ppm, respectively.

The waters in north Bingham Creek (S56) and Carrol Drain (S320) at 11800 South are moderately high in TDS, (835 and 1731 ppm), sulfate (183 and 633 ppm) and chloride (271 and 150 ppm), respectively.

Spring samples (S343 and S344) were taken at sites approximately 9 miles northeast of Copperton, considerably downgradient of Kennecott's operations. These spring waters are high in TDS (1974 and 1575 ppm) with elevated sulfate and chloride levels. This is typical of springs and the groundwater located in ground-water discharge areas that are also near the Jordan River.

Kennecott Facilities

Surface water samples were collected from the Bingham reservoir (S200), the Kennecott leach fluid circuit (S236), Bingham Pit (S237), leach dumps (S317), the treated evaporation pond inflow (S354), the old evaporation ponds (S350), the evaporation pond at 4000 West (S351), the South evaporation pond (S352), the untreated mine stream (S353), the North ore shoot (NOSE) water untreated (S355), the 80-acre clay lined pond (S356), and the Jordan River discharges to and from the settling pond near the cemetery (S357 and S358).

The following summarizes the water quality data results:

Reservoir (S200)

Consistent with Round 1 sample results, although improved slightly, the large reservoir waters (S200) are acidic (pH = 3.3) and are very high in copper, TDS, sulfate, aluminum, iron, manganese, nickel, zinc, radium and gross alpha and gross beta. Reservoir waters are moderately high in silver, arsenic, cadmium, chromium, nickel, lead and silica. Wells located immediately downstream and downgradient of the reservoir intercept poor quality waters with elevated concentrations of those same constituents which are found in the reservoir at high concentrations (Figures 16 through 19).

Evaporation Ponds (S354, S350, S351, S352, S356)

The evaporation ponds' waters range from neutral to slightly acidic and are high in TDS, sulfate and manganese. Elevated levels of aluminum, iron, copper, zinc, manganese, lead, molybdenum and nickel are also present.

Bingham Pit (S237)

Bingham Pit waters (S237) are of fair quality (pH=7.4) with a TDS level around 2200 ppm. Due to the fact that these waters intercept the natural ore body, the waters are high in radium, gross alpha, and gross beta. The pit waters are only slightly elevated in copper and manganese.

Leach Fluid Circuit (S236)

Leach fluid waters (S236) are acidic (pH=2.4) and, as observed in both Rounds 1 and 2 sampling results, are consistently very high in copper, TDS, sulfate, aluminum, iron, manganese, nickel, radium, gross alpha and gross beta and zinc. Levels of chromium, silver, arsenic, cadmium, and lead are slightly elevated.

Leach Dump (S317)

Waters from Kennecott's southernmost dump (S317) improved in quality since last year, but are acidic (pH=3.9-5.0) very high in copper, TDS, sulfate, aluminum, manganese and zinc. These waters are moderately high in chloride, iron, and nickel. These waters are of better quality but of similar quality to that of the leach fluid but are also high in gross alpha and gross beta. Waters in this dump area are collected in a pond and pumped back to the leach collection system.

It is of interest to note that although the water quality at S317 is, as would be expected, much better than at S236, chloride levels at S317 are considerably higher, (i.e, 487 to 717 mg/l compared to 206 mg/l). This data corresponds with chloride data obtained at the other well sites and surface sites in the southwest, northwest and east-central portions of the study area, where naturally occurring elevated chloride levels have been observed (P239, Cl=368 ppm; S318 Cl=444 ppm; W125, Cl=1270 ppm; W41A, Cl=319 ppm; W131A, Cl=326 ppm; W301, W302, W304, W306, Cl~500 ppm; W345, Cl=390 ppm). The distinctly higher chloride levels found in certain springs and wells may reflect water sources and flow paths separate from the relatively lower chloride, high TDS-sulfate waters affected and monitored at and adjacent to most of Kennecott's facilities.

Chloride may therefore be an indicator of flow systems whose recharge source is separate from seepage paths resulting from Kennecott's leach dumps, reservoirs and evaporation ponds, where relatively low chloride levels are observed. This needs to be investigated further as more water quality data are obtained from both new and existing wells.

Discharge Systems (S353, S355, S357, S358)

Discharge waters from the untreated mine stream (S353) are acidic (pH=4), very high in TDS, sulfate, aluminum, iron, zinc, manganese and nickel and have elevated levels of arsenic, lead and selenium.

Discharge waters from S355, the North Ore Shoot Extension (NOSE) are of fair quality, with neutral pH, TDS around 600 ppm and sulfate levels around 300 ppm. These waters were discharged to the Jordan River during peak runoff in 1984 and 1985. The water quality data obtained in May of 1985 indicate slightly poorer quality waters with respect to TDS and sulfate.

Discharge waters entering the holding pond (S357) near the Copperton cemetery are high in TDS, sulfate, manganese and lead, whereas waters discharged from this pond to the Jordan River (S358) are of fairly good quality.

GROUND WATER

The isoconcentration contour maps presented in Figures 16 through 19 illustrate the principal contaminant distributions in primarily the shallow aquifer near the reservoir, leach dumps, and evaporation ponds and the deep aquifer to the east. These maps are preliminary based on Rounds 1 and 2 water quality data, but confirm Round 1 sampling results, that metal contamination is localized and that surrounding private wells to the south and east, although high in TDS and sulfate, do not show elevated concentrations of metals. Other key contaminants associated with Kennecott's operations and the natural ore body also appear to be of limited distribution.

Alluvial (Shallow) Aquifer

Nineteen shallow monitor wells and three shallow private wells were sampled as part of Rounds 1 and 2 sampling (Table A-1, Appendix A). Kennecott's shallow monitor wells are located near the reservoir, along Bingham Creek, the evaporation ponds and along the leach dump area.

In addition to the new water quality data generated in Round 2 sampling, the Salt Lake County Department of Public Works, Division of Flood Control & Water Quality published the report "Assessment of the Shallow Aquifer In Salt Lake Valley" (January, 1985). The 1983 water quality data from eight of their sites, near the Jordan River, from 18000 South to 5400 South, are similar to some of the water quality data collected by Kennecott from the W300 series private wells along the Jordan River. The shallow aquifer waters near Riverton are high in TDS (2800 ppm), chloride (345 ppm), and sulfate (1300 ppm) and the waters are hard. The shallow aquifer waters near 9000 South are high in TDS (1600-3108 ppm); they are also hard and high in sulfate (690-1113 ppm). The shallow aquifer waters near 7800 South and 5400 South are high in TDS (1520-2260 ppm), in chloride (290-410 ppm); they are hard and high in sulfate (450-755 ppm). These data reflect the fact that the shallow aquifer along the Jordan River is indeed a ground-water discharge zone.

Reservoir

Rounds 1 and 2 water quality data from shallow wells K84, K85, K120, K100, and K26 downgradient from the reservoir indicate very poor quality low pH waters, very high in copper, with TDS of around 50,000 ppm, sulfate, aluminum, iron, manganese, nickel, silica, radium, gross alpha and gross beta. These waters also show elevated levels of silver, arsenic, cadmium, chromium and lead, due to seepage from the reservoir, past discharges of acidic waters down Bingham Creek and canyon underflow of natural and man-induced contaminants. Rounds 1 and 2 data are comparable, although Round 2 data indicate stable or slightly better quality than Round 1 data.

Bingham Creek

Rounds 1 and 2 water quality data from shallower wells along Bingham Creek (P196A, P197A, P191A, P193A, P192A) reflect waters with elevated levels of TDS and sulfate. TDS and sulfate levels at well P213A, located approximately one mile east of the reservoir, were around 98,000 and 40,000 ppm, respectively. However, these and other contaminant levels drop off significantly at a distance of approximately 1.75 miles east of the reservoir (i.e. well P196A), where levels of TDS and sulfate are only 1634 and 764 ppm, respectively. Rounds 1 and 2 data at these well sites are comparable, although TDS, sulfate and chloride levels did show an increase in well P191A..

Leach Dumps

Shallow wells along the leach dumps (P239, P220, P214A, K72, P234, P228, P225) intercept low pH waters with elevated levels of TDS, sulfate, magnesium, iron, manganese, lead, gross alpha, gross beta, zinc, nickel, cadmium and chromium. Elevated chloride levels (500 mg/l) appear to be characteristic of natural groundwaters in the southern part of the leach dump area near Butterfield Creek.

These waters have been impacted by the infiltration of leach fluid along the dumps. Leach fluid is no longer allowed to freely flow along the dumps but is controlled by the east-side leach collection system (Kennecott, (June, 1984)).

Groundwaters east and downgradient of the Lark tailings intercept similar constituents, especially manganese. The lateral and vertical distribution of the contaminants will be defined better following drilling and sampling of the new Phase I monitor wells.

Water quality data from two shallow private irrigation wells (W22 and W41A) located southeast of the leach dump area, approximately 2 and 2.5 miles west of Herriman, indicate that these wells intercept shallow groundwater of moderate quality. TDS and sulfate levels of waters from wells W22 and W41A are around 1400 mg/l, and 200 mg/l and 500 mg/l, respectively.

Monitor well sites P212A, P208A, and P211A monitor the shallow groundwater downgradient within three miles east of the leach dumps. The water quality at P212A, just north of the Lark tailings, is good, with a TDS of around 600 mg/l. The waters from wells P208A and P211 are poor, with TDS levels at 3100 ppm and 2000 ppm, respectively.

Evaporation Ponds

The shallow aquifer above and below the evaporation ponds is monitored via wells P207A, P240A, P190A, and P194A. The very poor water quality at P207A (e.g. TDS=14200 ppm) results from the fact that this well is drilled through the sludge on the pond bottom. The Technical Group has recommended that a replacement well be constructed at this site as part of the Phase II drilling program. Well P207A would then be grouted. Well P240A is a newly constructed shallow monitor well (Appendix B) located downgradient of

Kennecott's easternmost evaporation pond. The water quality in this well is moderately good, with TDS=1276 ppm and sulfate at 533 ppm.

Monitor wells P190A and P194A intercept moderately good quality groundwaters upgradient of the evaporation ponds. In fact, TDS and sulfate levels in P194A, located less than .25 mile from the old evaporation ponds, measure 400 ppm and 50 ppm. TDS and sulfate levels in P190A measure 1400 mg/l and 770 ppm.

In late 1983, the area east of the old evaporation ponds was discovered to be a major discharge zone for lateral seepage from the evaporation ponds. Kennecott completed a cutoff trench to intercept shallow lateral pond seepage. Continued frequent (generally monthly) monitoring of Kennecott monitor wells and private wells surrounding the evaporation ponds, particularly to the southeast, east and northeast, is ongoing.

Seepage from Kennecott's old evaporation ponds was observed along the banks of the Provo Reservoir Canal in the spring of 1985. A geotechnical engineer from Dames & Moore inspected the zone for potential stability problems. There was not enough inflow to cause any bank failure.

Perched Aquifers

Water level and hydrogeologic data collected to date do not indicate the presence of any perched aquifers on site. However, the U.S.G.S. (ref. Hely and others (1971), Figure 9) has defined perched aquifers in the study area between Herriman and Riverton and east of the Jordan River near Sandy.

A study conducted by Gary Christiansen of the Utah Geologic and Mineral Survey (UGMS) (March, 1985) of basement flooding along 11800 South near 3800 West did not reveal the presence of a perched aquifer, but rather the presence of both the deep confined and shallow unconfined aquifers. The UGMS stated that "Basement flooding is occurring as the water table in the shallow unconfined aquifer rises," and that "the water table is above the basement floors."

The UGMS also listed the potential sources for recharge to the shallow groundwater in this area to include: 1) precipitation, 2) stream flow, 3) unlined canals and flood irrigation, 4) septic tank soil absorption fields, 5) upward leakage from the deep aquifer and 6) leakage from Kennecott evaporation ponds.

Deep (Principal) Aquifer

Twenty-eight Kennecott monitor wells and sixty-five private wells, open to the deeper aquifer, were sampled in Rounds 1 and 2 sampling. Generally, throughout the study area and the valley, the water quality in the deeper wells is of better quality than that in the shallower wells. Rounds 1 and 2 water quality data from Kennecott monitor wells P190A,B; P191A,B; P192A,B; P193A,B; P194A,B; P197A,B; P207A,B; P211A,B; P212A,B; and P240A,B illustrate this fact.

In areas near the foothills of the Oquirrhs, near the reservoir and adjacent to the evaporation ponds, the water quality in some of the shallow and deep wells is nearly identical. This may be due to localized inter-aquifer flow between the shallow and deep aquifers. The isoconcentration contour maps (Figures 16-19) illustrate the areas and well sites where waters in the shallow and deeper zones are similar.

As discussed previously, the shallower wells along Bingham Creek and downgradient within 1.75 miles of the reservoir intercept low pH waters with elevated levels of copper, TDS, sulfate, magnesium, aluminum, iron, arsenic, cadmium, cobalt, manganese, nickel, lead, antimony and zinc (Appendix D, wells P213A, K26, K86). Deeper wells in this same area intercept waters of slightly better quality but they are still poor. However, there is significant improvement in the water quality of both the shallow and deep wells at a distance of approximately 1.5 to 1.75 miles east of the reservoir. The significantly better quality waters intercepted by shallow well P196A and deep wells K106 and K87 reflect this transition zone.

The deeper monitor wells surrounding the evaporation ponds are of significantly better quality than the shallower wells (Appendix C, wells P207B, P192B, P210b, P208B. Well P198 is open from 510 to 520 feet. Wells P240A and B are open from 100 to 155 feet and 280 to 360 feet (Appendix B, Figure B2). This appears to be due to the fact that P198 is closer to the evaporation ponds and receives shallow evaporation pond seepage waters flowing down along the outside of an improperly grouted well casing. In fact, the water quality in well P199, open from 685 to 695 feet, is poorer than that at P240A or B and may also be receiving vertical seepage. Grouting wells P198 and P199 was considered by the Technical Group. These wells will be pressure grouted to prevent future contamination to the ground waters.

In the later part of 1984, the TDS and sulfate levels in two private wells, W337 (B. Ham) and W338 (F. Wells) increased to 1664 ppm TDS and 784 ppm sulfate, and 1692 ppm TDS and 727 ppm sulfate, respectively (Appendix C). The source of the contamination may be the Kennecott evaporation ponds, possibly as a result of lateral seepage from the ponds, or possibly the result of leaching of historic materials deposited in the area. Kennecott will be, in Phase I drilling, completing two monitor well near these wells to determine the extent and cause of the contamination. Both well owners now receive their drinking water from the City of South Jordan. Mr. Ham's water system was already connected to South Jordan water. Kennecott assumed all costs incurred to connect Mr. Well's water system to the South Jordan water supply. Pumping and sampling of these wells were performed in May, 1985 to evaluate water quality changes. No changes were observed.

Deeper monitor wells east of the leach dumps (wells K70 and P211b) intercept moderately good quality waters, with TDS values of 831 and 320 ppm, respectively. Well K70 is only one mile east of the dumps and drilled to 313 feet. Well K70 also has slightly elevated gross beta levels. Well 211b is nearly three miles east of the dumps and open from 540 to 550 feet.

Waters of poor quality were intercepted by wells P202C, P241B and P208B, which monitor deeper zones southeast of the reservoir, from 530 to 570 feet, 560 to 600 feet and 420 to 433 feet, respectively. Water quality analysis from Round 2 samples from wells P202C and P208B correspond to the Round 1 data for these wells, particularly from well P202C.

Wells P202C and P241B are located in a topographic depression and may intercept a permeable channel that has allowed seepage flow from the large reservoir to flow to the southeast. It is unusual that the water quality in wells P208A and B is so much better than that in wells P202C and P241B, since wells P208A and B are located nearly one mile closer to the large reservoir and leach dumps.

The isoconcentration contour maps (Figures 16 through 19) illustrate that if the data from wells P202c, P241B and P208B are representative of the deeper aquifer water quality, it is possible that a highly permeable flow channel exists in this area which has allowed contaminant migration both laterally and vertically. Shallower wells P202a and P202b are dry.

Private Water Wells

Private wells located south and east of Kennecott's property are generally deep, from around 150 feet to 1218 feet with open zones generally from 180 to 400 feet. Most of these wells are used for irrigation, although the wells located just south and east of the evaporation ponds are used for drinking water (Appendix A).

Private wells located just south and east of the new lined evaporation ponds (W309, W310, W311, W312) generally meet Utah primary drinking water standards (Appendix C). Levels of TDS, chloride and sulfate are elevated and the waters are hard but are generally within or very close to Utah's primary drinking water standards.

Private wells located approximately one mile west of the Jordan River in the central part of the study area, (W301, W302, W304, and W306) do not meet drinking water standards for TDS, sulfate and chloride. Round 1 water quality data indicated slightly elevated lead levels above Utah primary drinking water standards. However, this was due to the fact that the laboratory analytical methods used prior to Round 2 1984-1985 sampling, were not accurate enough. The laboratory had been using straight flame analyses, with a detection limit of $\pm$ .1 mg/l. It currently uses a Zeeman graphite furnace, with a detection limit of $\pm$ .01 mg/l. Round 2 analytical results did not indicate elevated lead levels. The nitrate levels in these wells is also elevated in comparison to the other private wells and Kennecott monitor wells. In addition, Round 2 results indicate slightly elevated selenium levels in wells W304, W305 and W306. Round 1 data did not show this. These wells are used for irrigation. Selenium levels measured .016, .014 and .071 ppm, respectively. The Utah standard for selenium for agricultural waters is .05 ppm. These levels of selenium in these wells are higher than historic levels. If Round 3 data analyses also indicate elevated levels, two sets of samples from these wells will be obtained as part of the Round 3 sampling program.

Unlike wells W300 and W305, located in the same vicinity, but with much better quality water, wells W301, W302, W304, and W306 are flowing wells completed at shallower depths (around 175 feet versus 295 feet). In fact, these wells have been flowing since completed, except for well W306, which began flowing approximately ten years ago. It is believed that the casing may have failed and opened to the same flow zone which W301, W302 and W304 intercept. Well W306 thus, now appears to monitor flow in this zone and possibly the deeper zone. Water quality data from this well needs to be closely scrutinized, particularly with respect to any anomalous data results that aren't reflected in surrounding wells. Wells W182 and W345 across from these W300 series wells on the east side of the Jordan River have elevated manganese levels.

Published water quality data obtained in the later 1950's from private wells in this vicinity Kennecott (June 1984) indicate that private wells in this area intercepted poor quality waters with elevated levels of the same constituents as currently found. In 1958 well W-11 intercepted groundwaters with levels of TDS at 2390 ppm, sulfate levels at 1150 ppm and magnesium levels at 156 ppm. In 1978, well W-11 sulfate levels were around 1300 ppm and TDS levels around 3800 ppm. In 1983, sulfate levels were measured at 181 ppm and TDS at 766 ppm. The Utah State University (USU) multiple completion monitor well was installed approximately .5 mile west of W11 during the fall of 1983. It was constructed with open zones at 246 feet, 265.25 feet and 293.5 feet. The USU well construction specifications, geologic log and water quality data obtained during drilling are included in Appendix B. The geologic log indicates a shallow then a deep gravel zone, from 317 to at least 330 feet, which is overlain by a 7 foot "cemented" zone. This lower gravel zone may represent a lower confined aquifer zone. The saturated zones being sampled (from 240 to 330 feet) appear to monitor permeable sands, gravels and cobbles in which the water may be under pressure. The static water level rose to 205 feet after the borehole was drilled to 240 feet.

Poorer water quality was noted at shallower depths. During drilling, the sulfate concentration from 238 to 240 feet measured 2160 mg/l whereas at 320 feet the sulfate level measured 1380 mg/l.

A laboratory water quality analysis for the USU well is included in Appendix C. According to the USGS, this sample is representative of the ground-water quality at approximately 265 feet. The water quality in this well at this depth is high in sulfate, manganese and iron. These waters also appear to be alkaline, high in calcium and magnesium. The elevated sulfate and manganese may reflect ground-water impacts from Kennecott's evaporation ponds. However, the elevated iron levels are likely a result of well casing effects and/or possibly the result of using nearby canal waters as the drilling fluid. The Technical Group questions the integrity of this well.

The total dissolved solids and sulfate levels for wells located both north and south of the W300 series wells in Township 3 South Range 1 West were evidently fairly high, even back in the 1950's. TDS and sulfate levels generally ranged from around 500 to 1000 ppm and 100 to 600 ppm, respectively.

Laboratory water quality data from private wells W322, W131B, and W125 (now Kennecott's) located south near and along Butterfield Creek, indicate fairly high levels of TDS (1500 to 2970 ppm), sulfate levels of 330 to 500 ppm, and elevated chloride levels of 1270 ppm at W125). The aquifer in this area may be receiving poor quality recharge waters from the Oquirrhs. The southern part of the Oquirrhs was, as discussed previously, very heavily mined for lead, zinc and silver. Waters from W125 are slightly elevated in lead.

Private wells W31 and W189, located north and northeast of Kennecott's operations, intercept waters of very good quality (i.e. TDS values are 525 and 400 ppm, respectively). Well W31 is a Copperton City production well open from 149 to 1218 feet and located approximately two miles north of the reservoir. Well W189 belongs to Interstate Brick and is open from 350 to 637 feet.

Well W189 is 3.4 miles east of the reservoir along Bingham Creek. The fact that this well and Kennecott's production well (K-109) are open to the deep aquifer and intercept good quality waters which are stable, versus poor quality water at Kennecott's monitor wells to the west, particularly the shallower wells, demonstrates that the deep aquifer at these two well sites has not been degraded.

Private well W27 in the Town of Copperton, completed at 210 feet, intercepts very good quality groundwater. TDS and sulfate levels measure 798 ppm and 96 ppm, respectively.

Private wells W322 and W323, within and upgradient from the Town of Herriman, respectively, indicate that sulfate and chloride levels in this area have risen over the past year. Since W323, the more southerly well,(and upgradient from mining impacts), shows similar trend observed increases, it is very likely that these observed trends are natural.

Radionuclide data results from sample sites obtained for Round 2 in 1985 are incomplete. There was confusion as to which sites were to be monitored. Only nine sample sites were analyzed for radionuclides in Round 2. All sites scheduled for radionuclide analysis will be analyzed in Round 3 (Table 3). Data from Round 2 sites are included at the end of Appendix C. Wells W301 and W310 are the only two sites exceeding EPA drinking water levels for gross alpha at 11(+9) and 5(-1) pCi/l, respectively. The radionuclide data from Round I sampling, which was compared to Utah Drinking Water Standards in Report I, is also included in this report.

Four private wells, W185, W326, W328 (in the south-southeastern corner of the study area and Copperton's well (W31) to the north-northwest have gross alpha levels of 13.1, 13.6, 10.8, and 5.4 pCi/l, respectively. Wells W328 and W326 measured gross alpha levels of 10.8 and 13.6 pCi/l, respectively. Radium values, however, were low, at 1.0 pCi/l. The water quality in these wells is generally good. The TDS and sulfate levels in these wells are relatively low (TDS from 444 to (981 at W328 near the Jordan River) and sulfate levels from 21 to (170 at W328 near the Jordan River).

Slightly elevated fluoride levels were observed in wells P198, P231 and private well W340. Well W340, Utah Roses irrigation well, is located in the southeast corner and taps geothermal waters. The fluoride levels in W340 waters have measured 3.3 and 2.5 ppm over the past two years. Well W340 waters are also elevated in arsenic and manganese. Kennecott's well waters from P198 (of questionable integrity), measured fluoride levels from 1.09 to 4.4 ppm. Waters from well P231, just above the Lark tailings, have measured 3.0 and 2.88 ppm in fluoride levels.

KENNECOTT SURFACE WATER MANAGEMENT IN 1984-1985

During 1984 and early 1985, Kennecott upgraded its lime treatment facility and increased the amount of lime treatment to runoff waters from Bingham Canyon by a factor of two with the addition of another lime slaker unit and an automated lime treatment facility. Treated discharges to the old and new (lined) evaporation ponds continued in order to manage the excess precipitation that occurred in 1983 and again in 1984 and early 1985. Over 5000 acre-feet of excess runoff occurred in the Bingham Canyon watershed and was routed to Kennecott's evaporation ponds, 480 acre-feet of treated water was pumped to the Jordan River. Discharge of excess NOSE and Bingham Canyon Creek "good" quality waters were routed to a settling pond near the reservoirs, and discharged to the Jordan River.

Old evaporation pond dikes were raised for additional storage capacity and excess surface waters were diverted into the mine pit. A detailed description of the historic surface water management of Bingham Canyon stormwater is presented in the report by the Utah Copper Division, Environmental Engineering Department (August, 1984). A map illustrating the water diversions and treatment in 1984 is presented in Figure 20. Discharges to the Jordan River in 1985 began in mid-February. The discharge of treated north ore shaft and mine pit water was terminated on April 24, 1985. Treated excess storm runoff discharge collected as seepage was terminated on April 11, 1985. Due to projected future increased dewatering in the shaft, the discharge of treated north ore shaft and mire pit water is expected to resume and will comply with the existing NPDES permit.

PHASE I MONITOR WELL DRILLING PROGRAM FOR 1985

The technical basis and details for the Phase I monitor well locations and depths are presented in Section 2.0 "Project Description: Objectives and Work Scope" of the "Work Plan," included as Appendix F to this report.

The Phase I monitor well drilling program was originally scheduled for 1985. The entire five-year study was delayed considerably in 1985 as a result of questions and confusion as to the project goals, work scope and monitor well drilling specifications and finalization of an agreement with the State Department of Health and the County. Consequently, the Phase I drilling, which was originally scheduled to include completion of 27 new monitor wells at 17 sites, to better define subsurface geology and contamination on-site, but particularly off-site, may not be completed in 1985. Every effort will, however, be made to conduct this first critical phase of drilling as soon as possible.

GROUND-WATER AND SURFACE WATER SAMPLING AND MONITORING, ROUND 3

Ground-water and surface water sampling and monitoring for Round 3 will be more extensive than Rounds 1 and 2, both in the number of sample sites (new monitor well sites drilled) and in the frequency of samples collected.

Table 2 lists the water quality constituents that will be (and/or have been) analyzed and Table 3 lists the existing sample sites that will be sampled.

All 156 sample sites (68 private well sites, 47 Kennecott monitor wells, 41 surface water sites) will be sampled at least once per year. Eighteen sample sites located in strategic areas will be sampled an additional two times per year for critical contaminant parameters (Table 3) and evaporation pond monitor wells will generally be sampled monthly.

In addition to the above increased sampling, and as per the UGMS' Gary Christiansen's recommendation (Appendix G), Kennecott will monitor water levels in the new evaporation ponds and surrounding wells K201, P190A & B, and new well 17S to determine if there is a correlation in water level fluctuations in the ponds and surrounding wells. If not, then there would be no need to install a new monitor well in Section 23 approximately one mile upgradient from the ponds, as the UGMS had originally proposed.

RECOMMENDATIONS

Preliminary Contaminant Flow Modeling

Intera Technologies recommended to Kennecott that a preliminary contaminant ground-water flow model could and should be developed in 1985 from existing and new subsurface geologic and water quality data. All of the historic water quality data from 1975 through 1984 is on file in Intera's computer in Houston, Texas, for use in this model.

The main purposes in completing a preliminary model at this time are: (1) to refine previous contaminant migration estimates (EAS, October, 1984), which will necessarily include inflow/outflow model boundaries; and (2) to pinpoint the critical areas, both laterally and vertically, particularly on-site at contaminant sources, where data gaps exist.

The Technical Group has agreed that a preliminary model is appropriate at this time, to be refined as additional data are obtained from drilling and sampling new monitor wells.

Establishment of Background Water Quality

Based on the historic (1975-1984) water quality data from upgradient and northern and southern distant monitoring sites, and historic published water quality data, Intera Technologies will complete an assessment of background water quality for natural surface water sites, the shallow and the deep ground-water flow systems in the study region.

Phase II Drilling Program

The Phase II drilling program will be designed primarily to monitor contaminant source areas on-site, and off-site if necessary. Exact well locations for Phase II cannot be defined until the Phase I drilling and sampling programs are complete and data evaluated. Consequently, Phase II drilling may begin in 1986 and extend into 1987.

The Utah Geologic and Mineral Survey (UGMS), EPA Region VIII, Utah Department of Health, Utah Division of Oil, Gas & Mining and the Utah Water Research laboratory at U.S.U. submitted written recommendations concerning new sample site locations. These recommendations which were submitted in March, 1985, are included in Appendix G. A map illustrating the Phase I drill sites and some "potential" Phase II drill and monitor sites (based solely on the aforementioned written recommendations) is also presented in Appendix G. Some or all of these sites may be included in Phase II drilling, depending on what the Phase I data indicate.

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